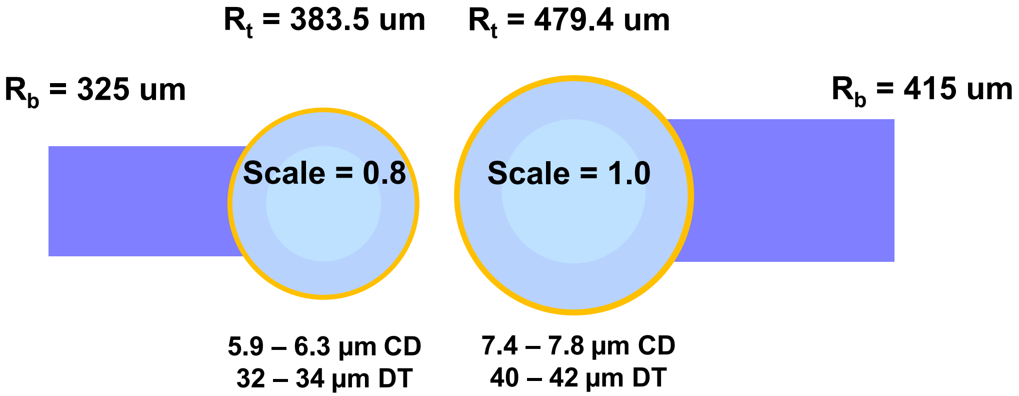
SAND2021-13963C

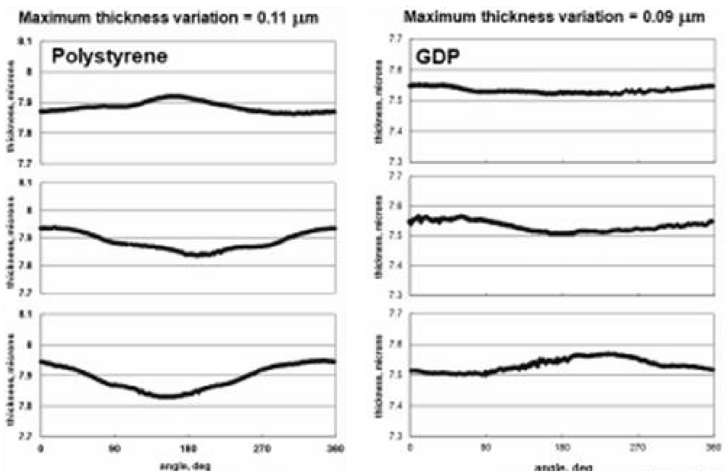
Laser-Direct-Drive Cryogenic Implosion Performance on OMEGA Versus Target and Laser-Spot Radius

UR LLE

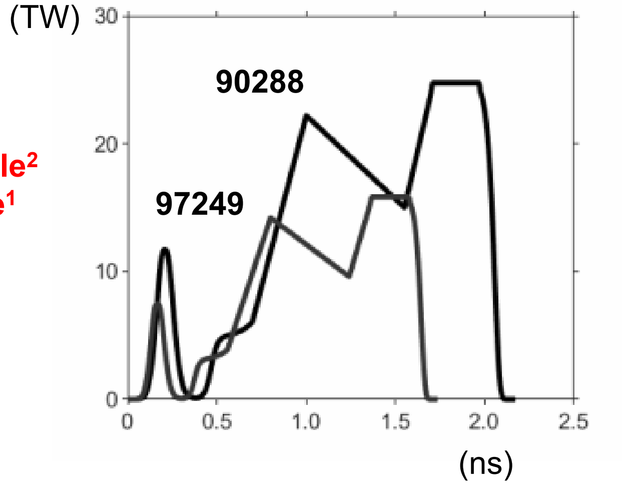
Dimensions ~ Scale^1

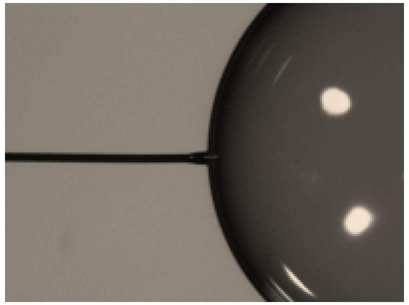


Flaws ~ Constant



Power ~ Scale^2
Time ~ Scale^1





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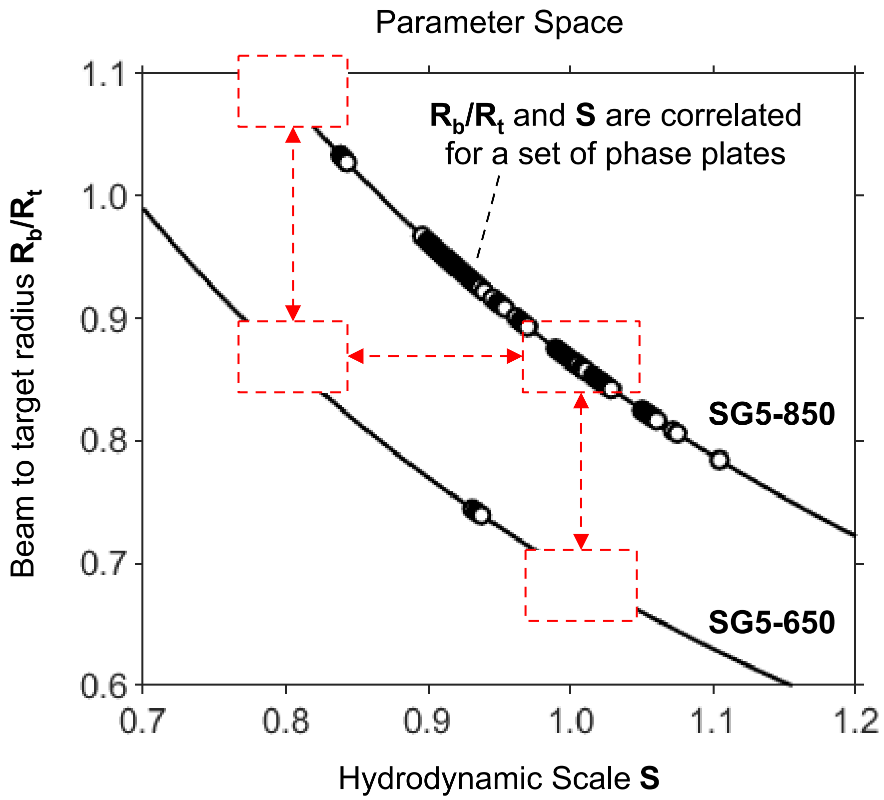
Data on scale (S = target radius/reference) and beam-to-target radius (R_b/R_t) have been used to reduce uncertainty orthogonal to standard database

UR LLE

- **Measured yield and areal density increase as $S^{5.0\pm0.2}$ and $S^{1.8\pm0.2}$, respectively [Euler ~ S^4 and S]**
- **Experimental mitigation of the "beam mode" or beam radius can increase yield a factor of 1.4**
- **Calculations in 2-D predict similar trends, and are explained by laser and target flaws that do not scale (e.g., imprint, target offset, roughness)**



Goals: validation of stat model, perspectives on data vs theory, requirements for high gain

Collaborators

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and

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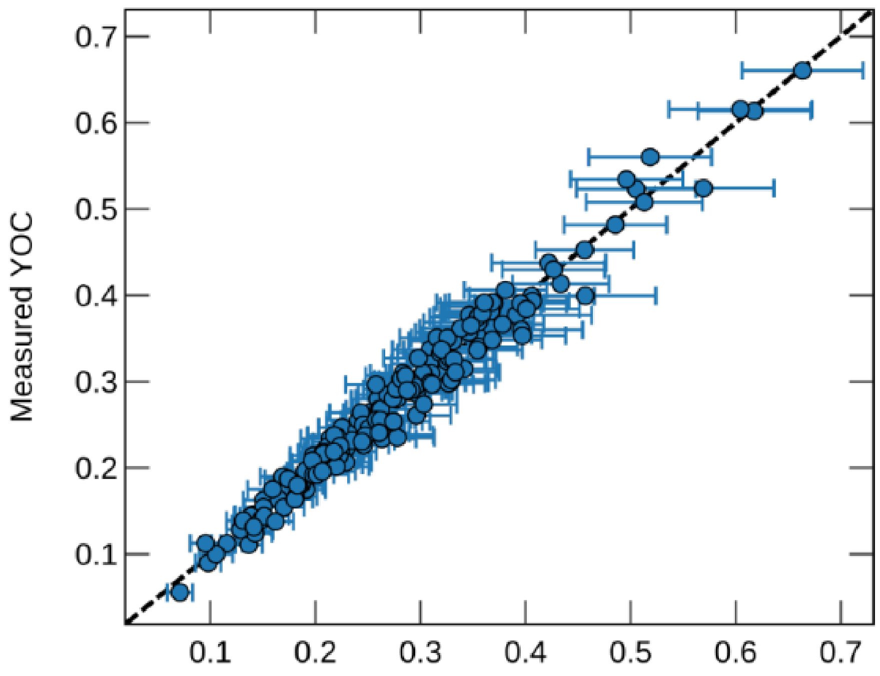
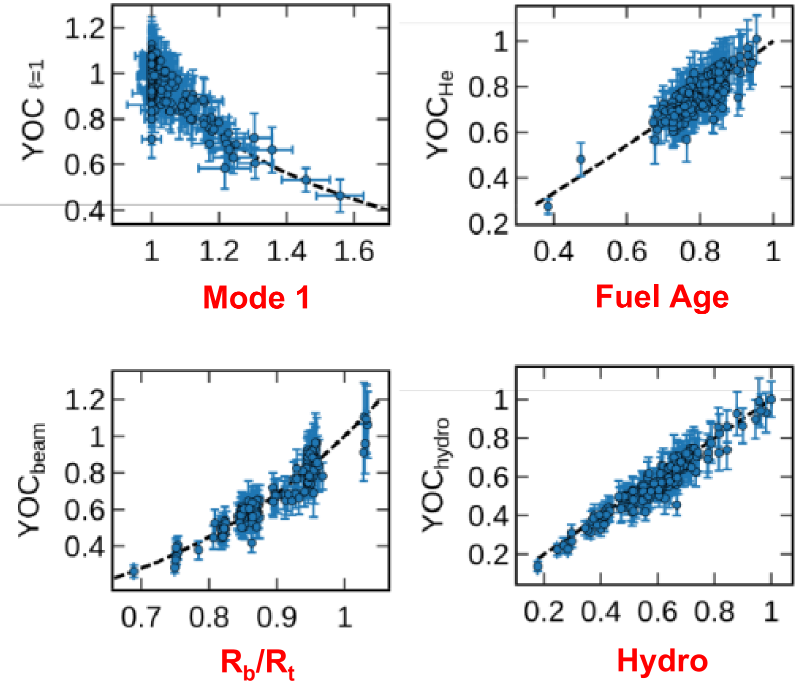
Progress in direct drive has accelerated with the use of statistical methods



$YOC_{PREDICTED}$ ~
Function(Mode 1, Fuel Age, R_b/R_t, Hydro)



Individual sensitivities are being studied with focused experiments and simulations

Power laws are a useful way to compare data with theory, simulations, and the statistical model

Best case — *Possible corrections to energetics, stability, and compression*

$$Y_{MSR} \sim Y_{1\text{-}D}\ (S)^{X_1}\ (v)^{X_2}\ (\alpha)^{X_3}\ (R_b/R_t)^{X_4}$$

Mechanisms in 1-D and 3-D?

$$X_1\ \ln(S) \sim \ln(Y_{MSR}/Y_{1\text{-}D}) - X_2\ \ln(v) - X_3\ \ln(\alpha) - X_4\ \ln(R_b/R_t)$$

Capsule size

Additional terms

Impact can exceed scale (e.g., $X_4 >> X_1$)

Source of uncertainty and potential bias

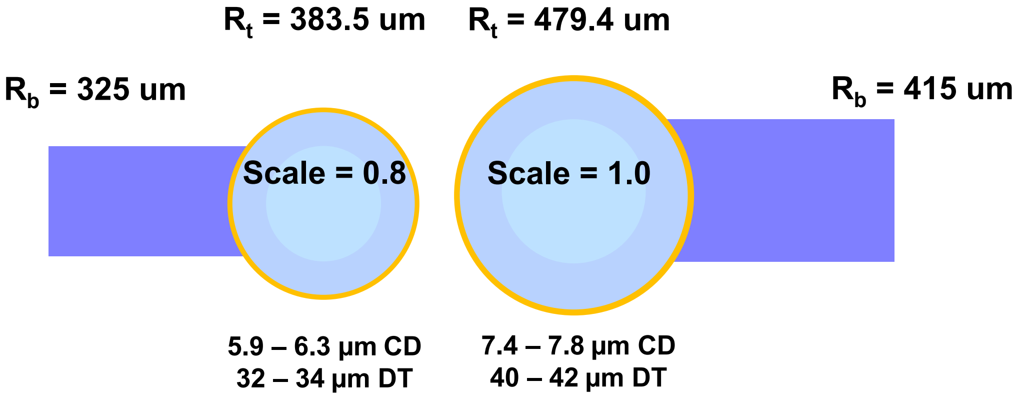
S = Hydrodynamic scale
v = Implosion velocity
α = DT adiabat

R_b = Radius of laser beam
R_t = Radius of target

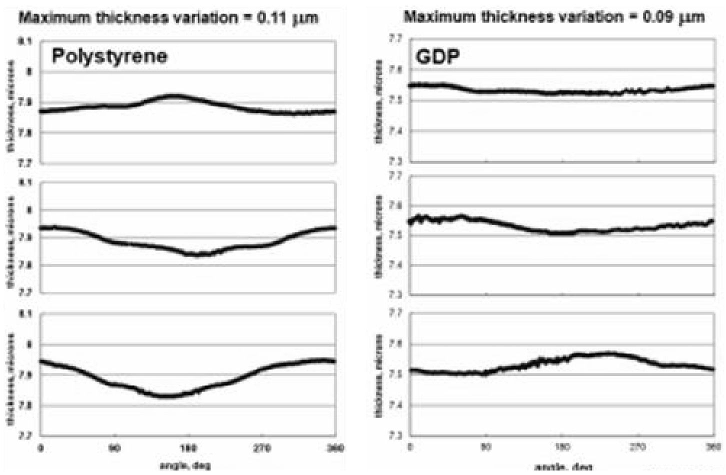
Experiments can be ‘designed’ to reduce uncertainties vs scale, or any other parameter

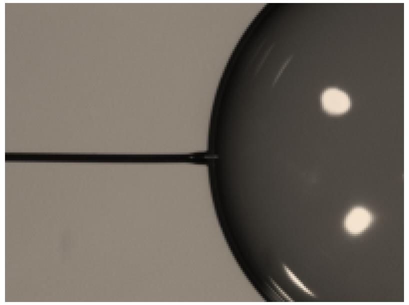
For all of the work here, comparisons are simplified by maintaining constant pulse shape, shock-timing, adiabat, and in-flight aspect ratio or IFAR

Dimensions ~ Scale[1]

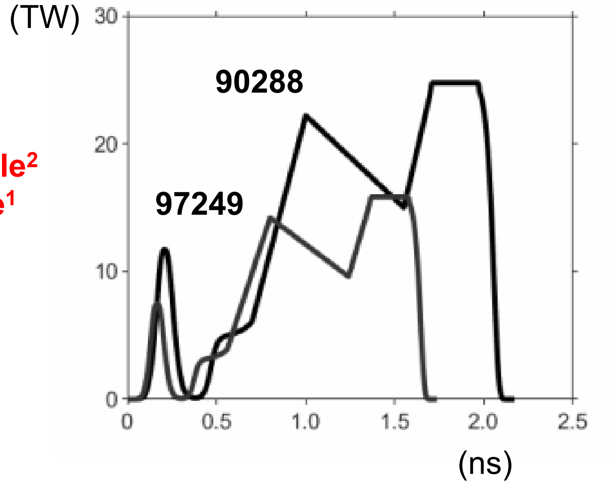


Flaws ~ Constant

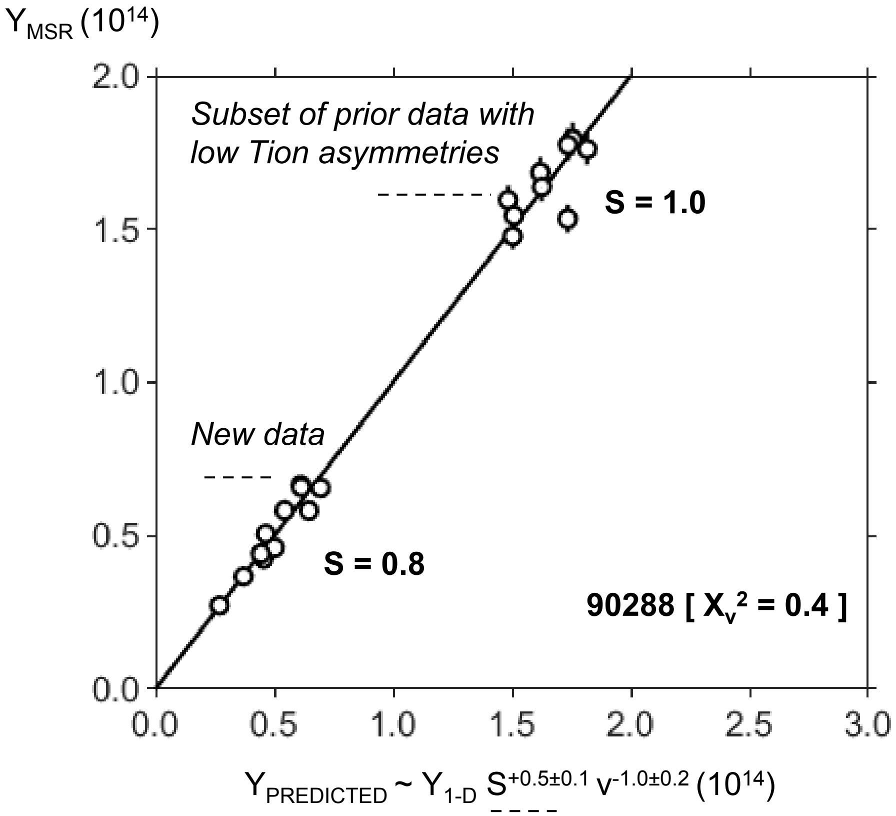


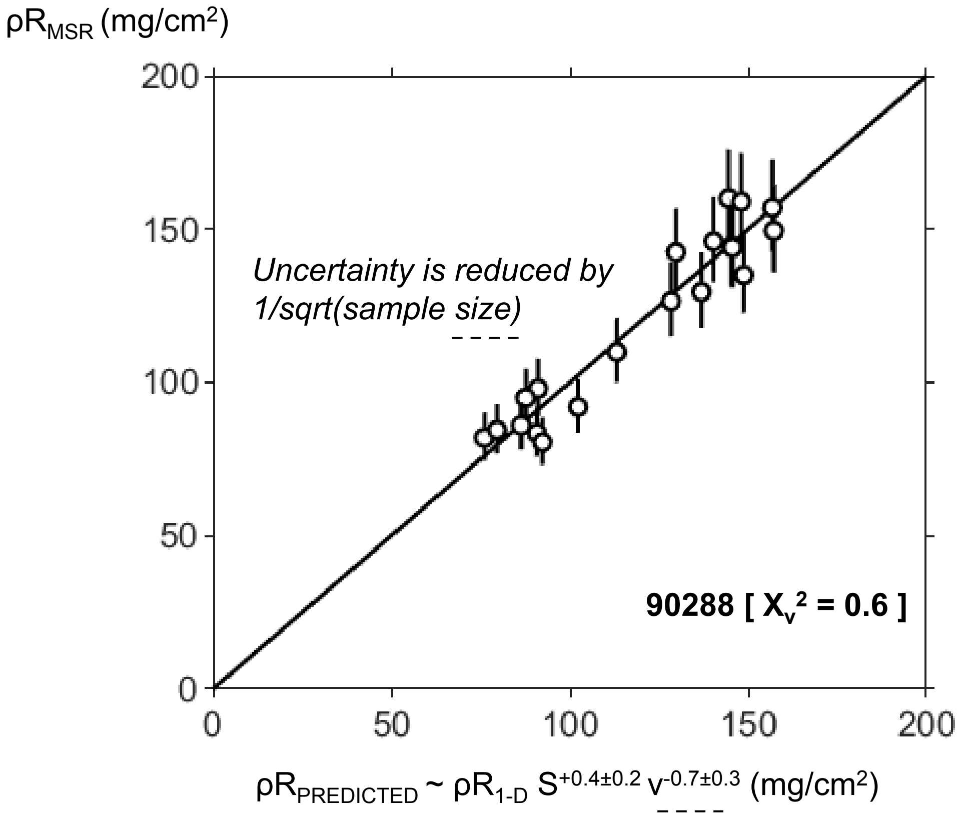


Power ~ Scale[2]
Time ~ Scale[1]



Yield and areal density **improve with larger capsules, relative to 1-D theory**



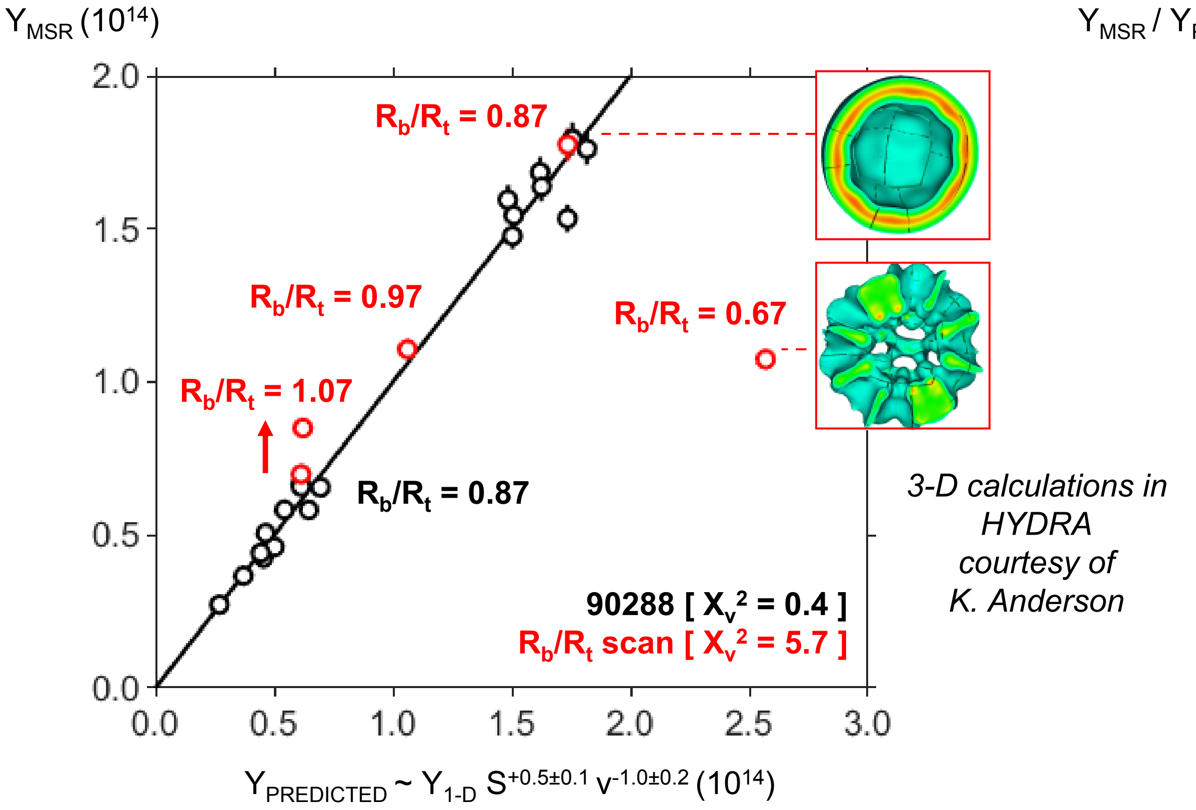


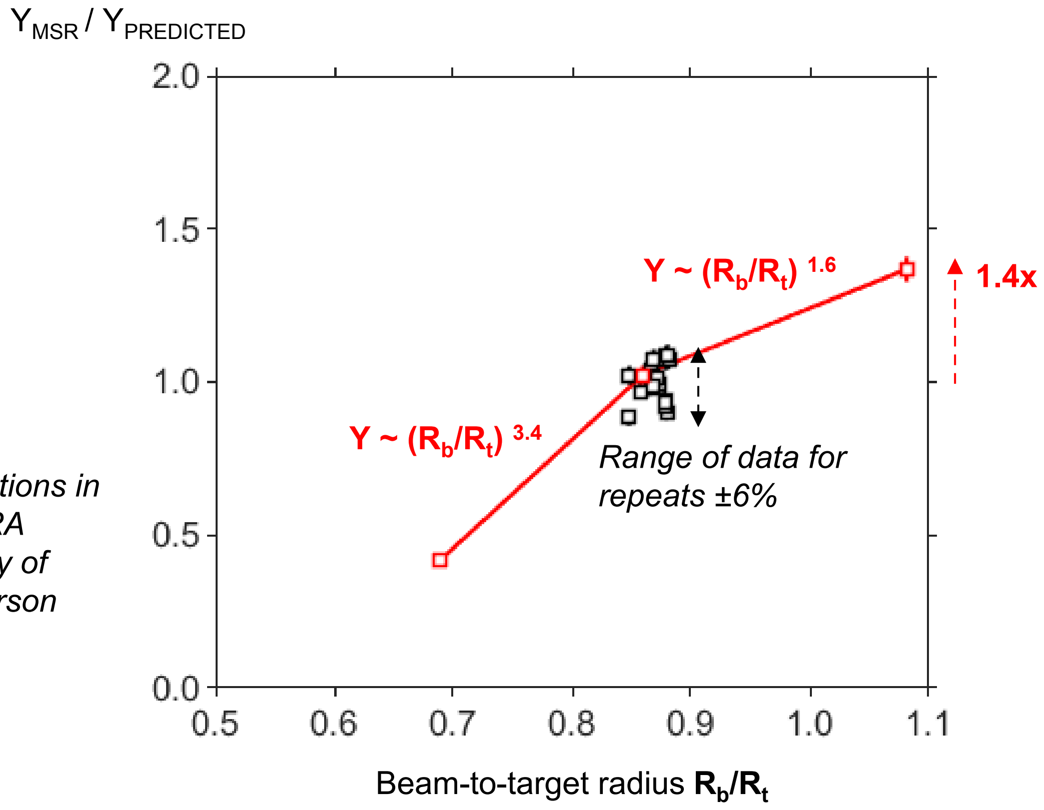
Hydrodynamic scale is main focus of study

Velocity is predictable, the most important term in 1-D, and findings suggest instability

Statistical significance comes from precision of OMEGA laser, ~ 10 shots at each scale

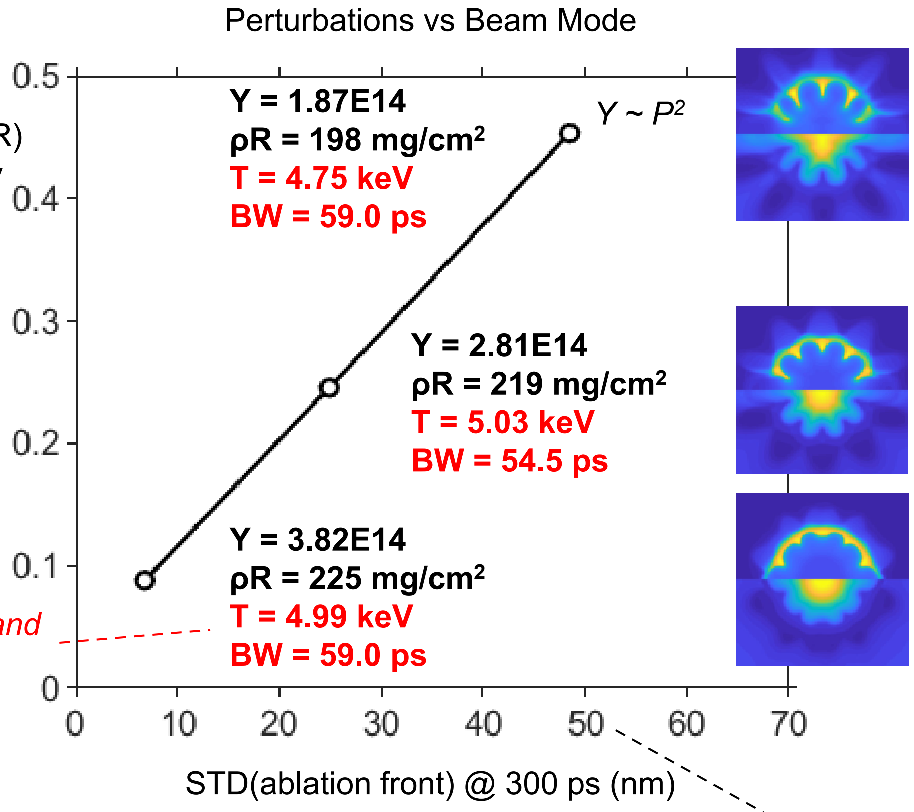
Beam-to-target radius (R_b/R_t) can also be used to improve performance





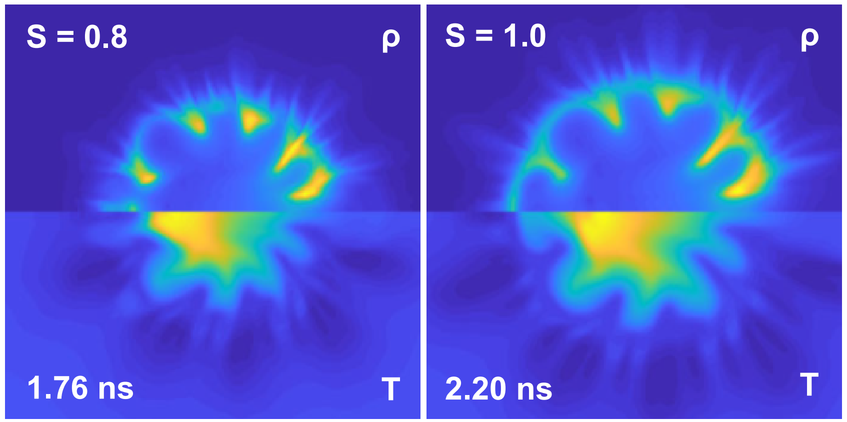
Interpretations may be a function of sampling, and final analyses will require more statistics

Calculations in DRACO can be used to predict performance vs flaws (in 2-D)



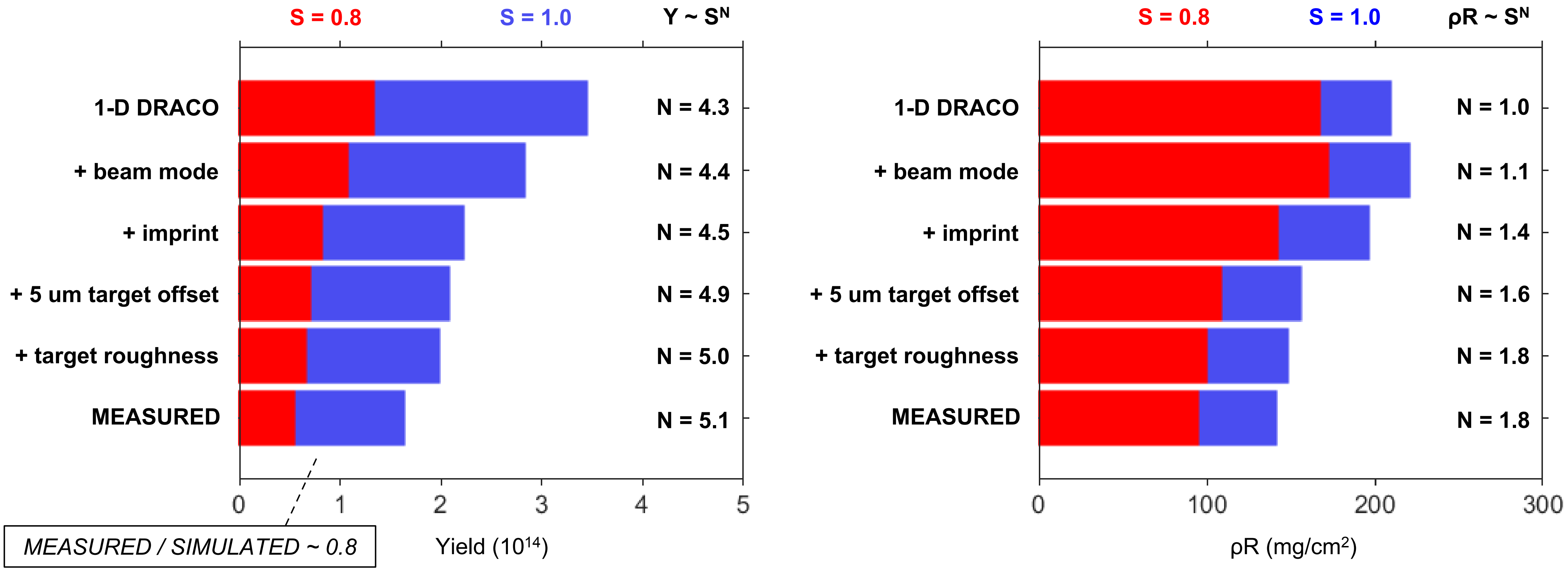
Changes in Tion and BW ~ uncertainty

Equivalent value at 1 g/cc is 200 nm



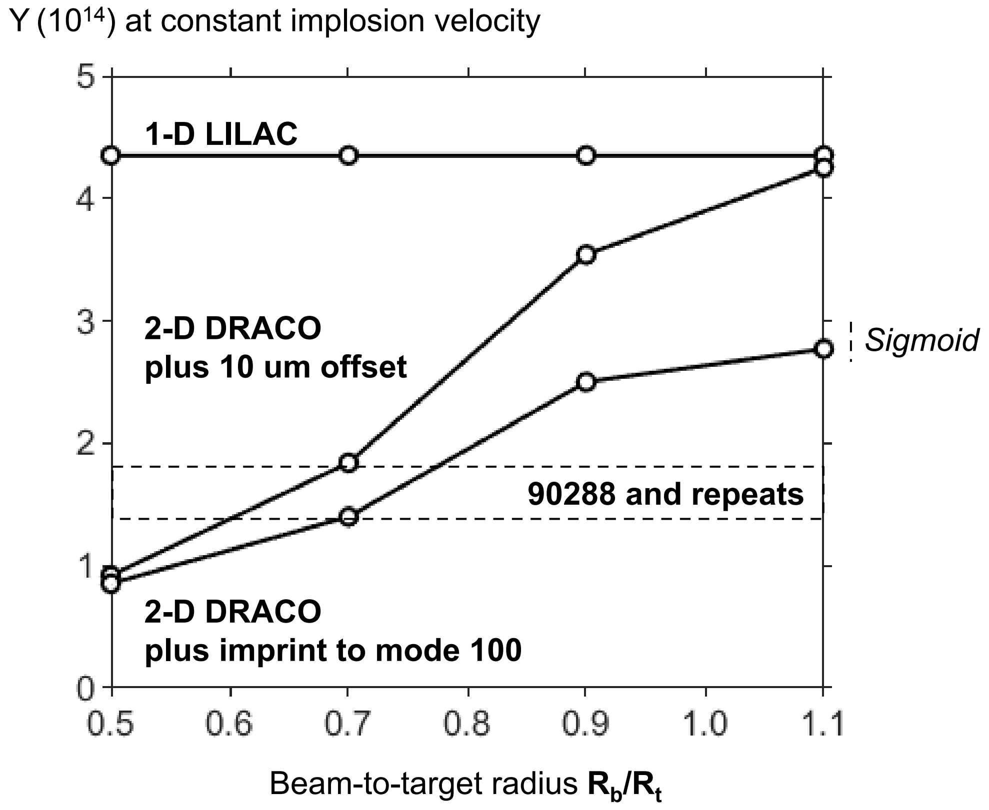
Calculations in DRACO with nominal levels of imprint, capsule roughness, and target offset (5 um) at two different scales. The hot spots are similar, but not self-similar.

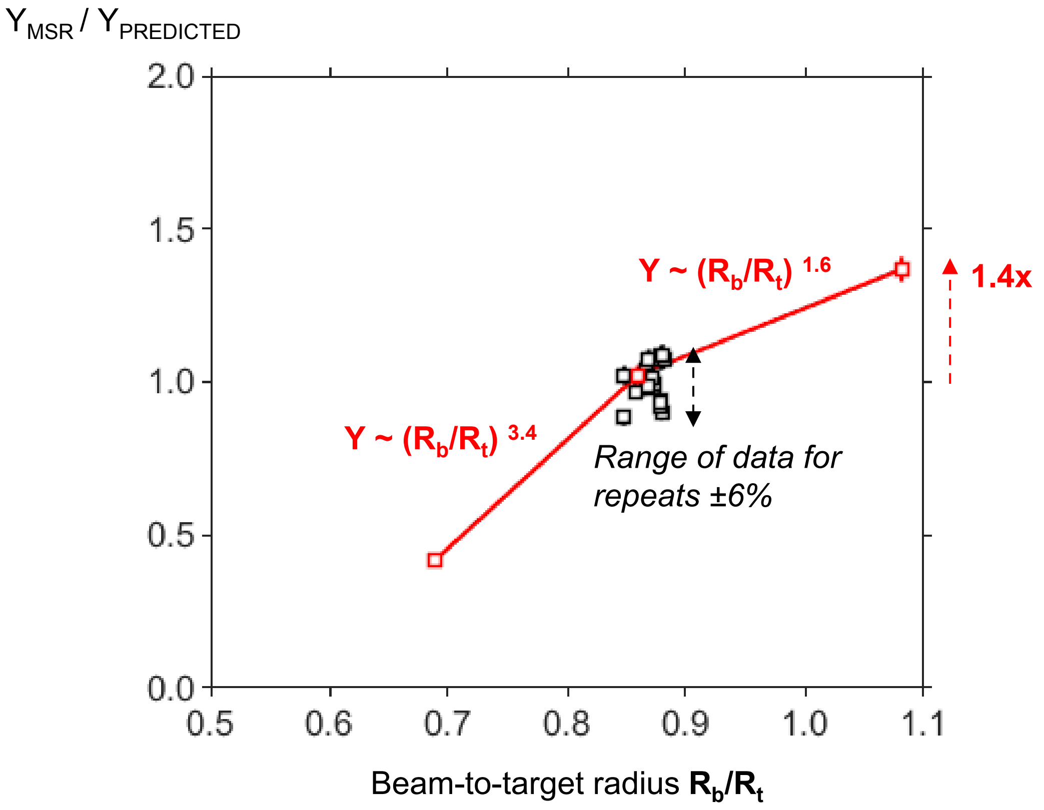
Small targets show more degradation by flaws of a given size, and cause performance vs scale > 1-D expectations



2-D calculations are not a perfect surrogate for 3-D (i.e., ASTER or HYDRA)

DRACO also predicts sensitivities in data to R_b/R_t, but estimates depend on physics models (e.g., Schurtz vs flux limiter in picket etc.)

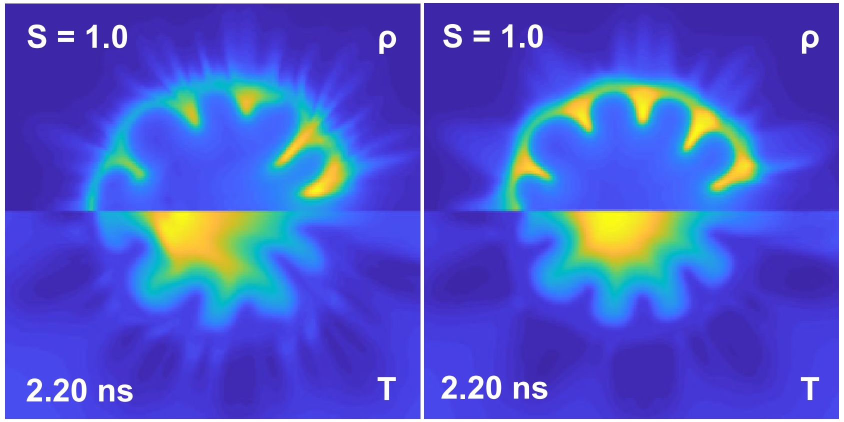




Final comparisons will also depend on a statistical treatment of flaws, more data

Potential of direct drive is a function of progress at OMEGA, and taking advantage of scale and beam-to-target radius

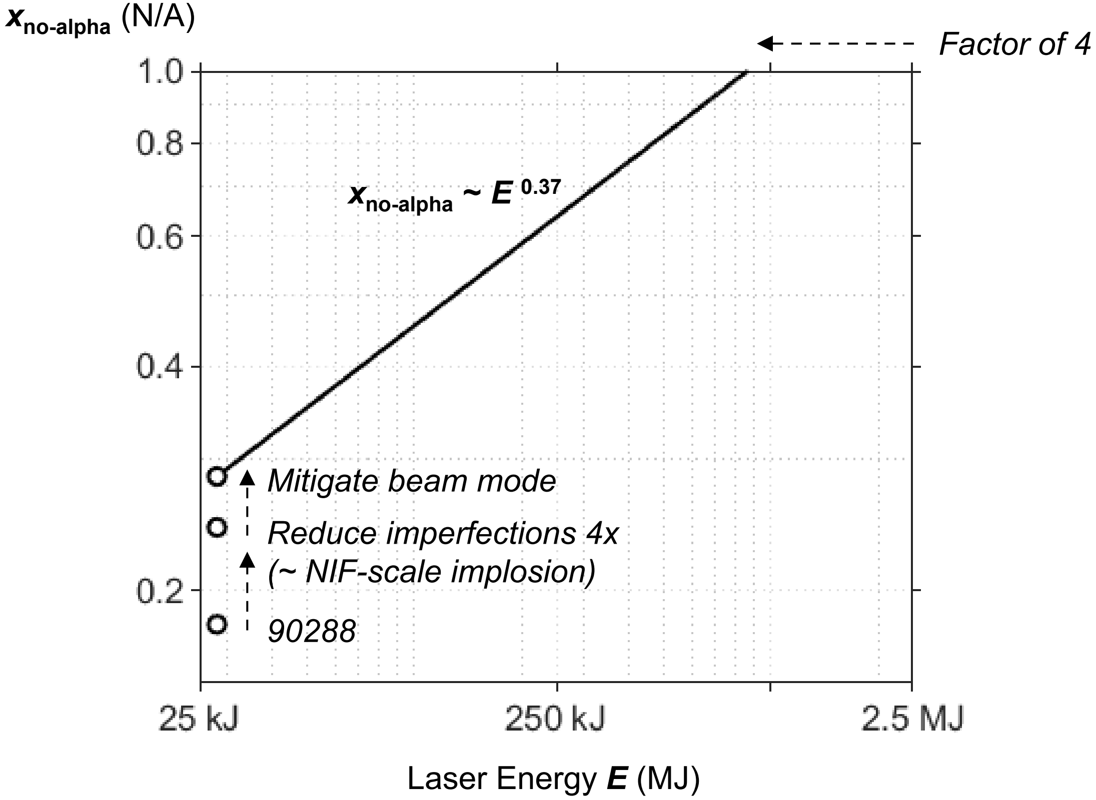
- IF OMEGA imperfections, imprint, etc., were smaller by 4x



Y = 1.96E14
ρR = 147 mg/cm²

Y = 2.65E14
ρR = 199 mg/cm²

- OMEGA-like targets at NIF scale could behave similarly
  - Target offsets, roughness, etc. do not scale
  - Thick targets have more beta-layering
  - Laser imprint is only critical for 50 to 100 ps



Low adiabat implosions are more unstable, and may have more to benefit

OMEGA database has been expanded with single variable studies in hydrodynamic scale (S) and beam-to-target radius (R_b/R_t)

- Measured yield and areal density increase as $S^{5.0\pm0.2}$ and $S^{1.8\pm0.2}$, respectively [Euler ~ S^4 and S]
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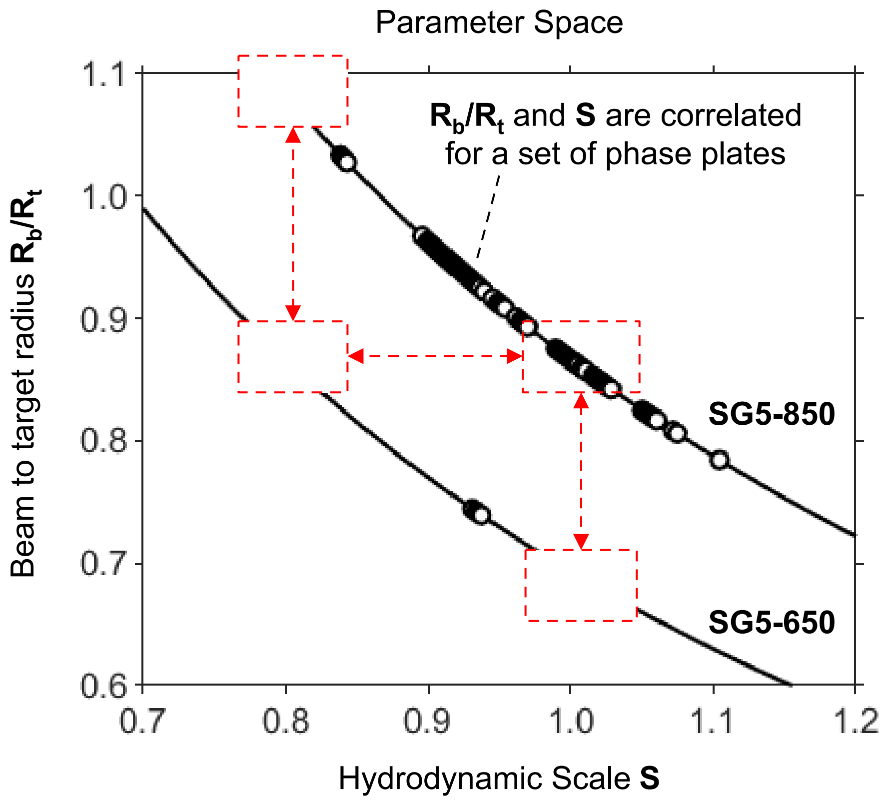

Future work to consider tradeoffs in pulse shape and timing since gain ~ $M_{DT}\ \rho R_{DT}\ /\ (\rho R_{DT}+6)$

Backups